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The consequences of the diurnal variation of soil respiration for soil budgets from up-scaled day-time measurements

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Introduction

Precise measurement and modelling of soil respiration (R_s) is important for correct estimation of annual ecosystem carbon budgets. Here R_s is particularly important to partition autotrophic respiration into below and aboveground parts (Wu et al. 2013, Agric. For. Meteorol., 181, 95-107). Like in this study, R_s is often estimated with manual chamber measurements performed at regular intervals in a number of different plots. While such measurement schemes may capture the variation in R_s on a spatial and seasonal scale, it does not fully catch the diurnal variation, as manual measurements normally are performed during day-time working hours. Up-scaling to daily R_s values from day-time data requires that they are representative; otherwise the daily estimates are systematically biased.

Figure 1 (left): One of eight automated soil respiration chambers (8100-104 Long-Term Chamber, LI-COR Biosciences).

Figure 2 (right): The manual soil respiration chamber (8100-102 Survey Chamber, LI-COR Biosciences).

Methods and Objectives

Eight automated soil chambers each measured R_s once in an hour throughout a year in a temperate Danish beech forest (Figure 1 and 3). In parallel 84 manual measurements of day-time (09:00-15:00 CET) R_s were made every 2 weeks (Figure 2).

The study had the following objectives:

- Investigate the seasonal and diurnal variation of R_s in a temperate beech forest.
- Scale up measured R_s to different annual R_s budgets based on the manual measurements and the automated hourly measurements.
- Study the consequences of using up-scaled day-time measurements of R_s for estimating the annual soil carbon budget in a temperate forest.
- Yield a correction factor than can be used to correct manually measured day-time R_s data to take the diurnal cycle of R_s into account.

Results

The hourly automated measurements (Figure 4) showed that day-time R_s values were consistently lower than at night-time. This was particularly surprising as night-time soil temperatures are lower than at day-time. Consequently the up-scaled R_s based on daily values underestimated the annual R_s value, compared to using continuous hourly data (Figure 5 and 6). The respective systematic errors depended on season and varied on a monthly mean from 5 % to as much as 22 % (Figure 6). When correcting the carbon budget from manual day-time measurements, the annual budget increased 14 % from 708 to 810 g C m^{-2} yr^{-1}, which corresponded well with the 824 g C m^{-2} yr^{-1} calculated from the automated measurements.

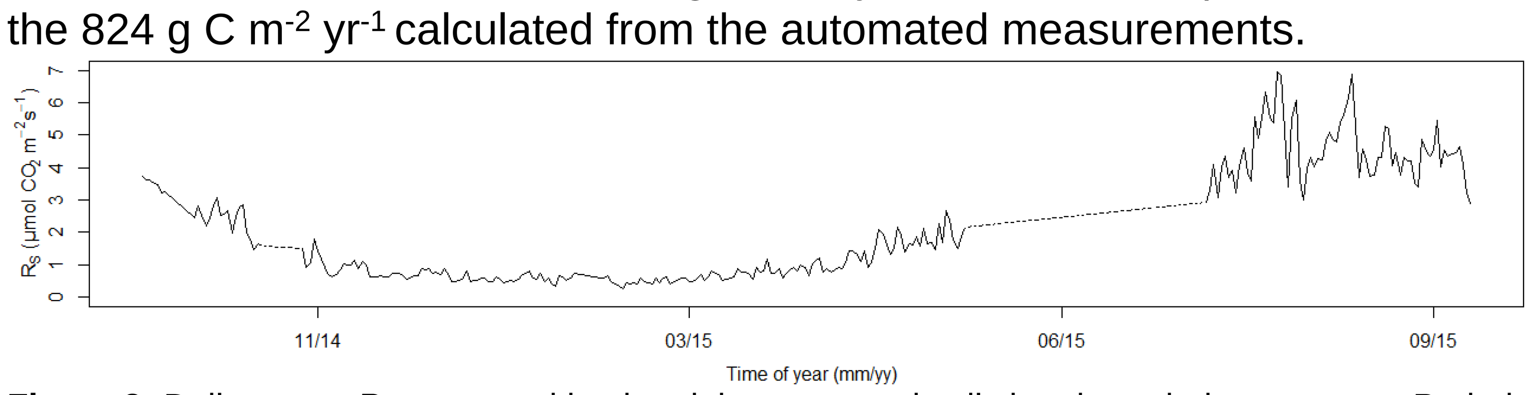

Figure 3: Daily mean R_s measured by the eight automated soil chambers during one year. Periods of missing data due to system failure is shown with a dashed line.

Diurnal R_s throughout the year

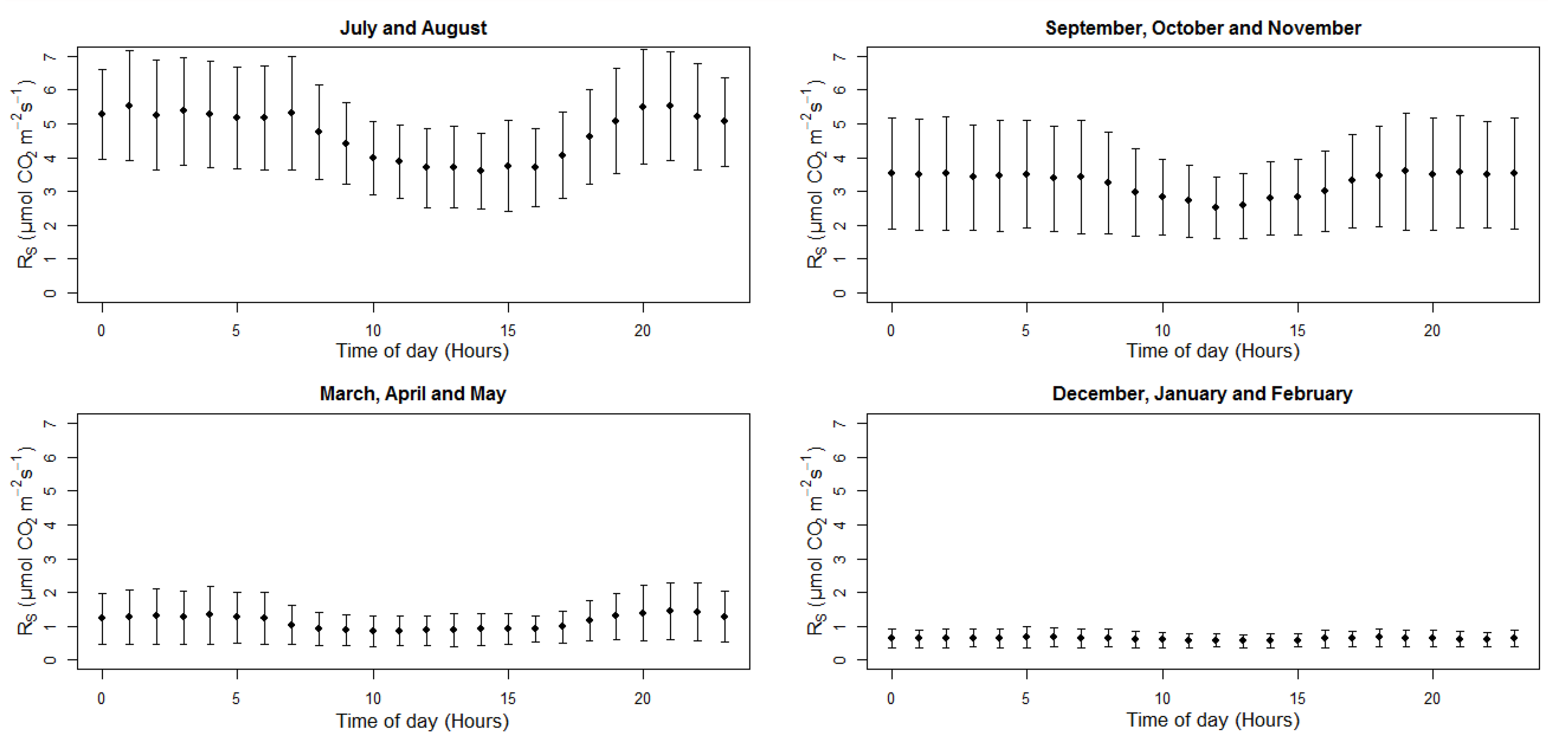

Figure 4: Diurnal course of R_s for 4 seasons measured by the automated chambers. Each data point represents a mean value of R_s for the period. Error bars show standard deviation. The largest diurnal variation in R_s is seen in the summer months (July and August), followed by spring (March, April and May), autumn (September, October and November). The smallest diurnal variation is seen in winter (December, January and February).

Up-scaling error of annual R_s

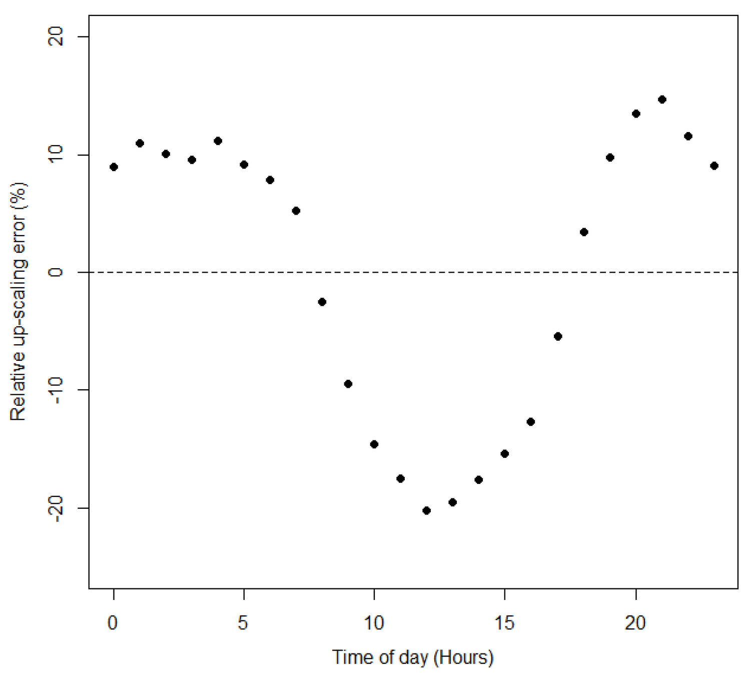

Figure 5: Relative up-scaling error of annual R_s, where data for one hour per day is used, compared to annual R_s based on 24-hour data. Annual R_s based on data between 7-8 and 17-18 lie closest to the 24-hour annual R_s.

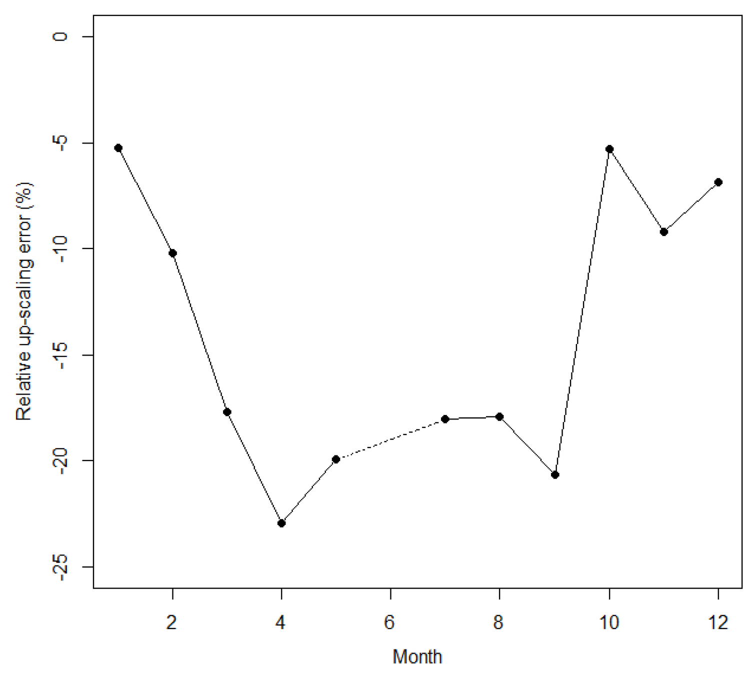

Figure 6: Relative up-scaling error on a monthly basis of using daytime data compared to 24-hour data. For each month, R_s based on daytime measurements underestimate R_s compared with 24-hour data.

Conclusions and Outlook

- The annual R_s budget based on day-time values of R_s led to an underestimation of the annual R_s, compared to when the full diurnal cycle was taken into account.
- We advocate carefully investigating the diurnal pattern of soil respiration across all seasons when up-scaling day-time flux data, since neglecting the diurnal cycle may considerably bias the up-scaled annual budget.

Acknowledgements

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